WBS DICTIONARY

This dictionary gives a succinct definition of some of the most important tasks included in the WBS and describes both DOE and NASA activities.

1.1 Structural Components

1.1.1 EBIS Hardware

The mechanical components which comprise the EBIS source.

1.1.1.1 SC Solenoid

The superconducting solenoid is a major element of EBIS and its function is to focus the electron beam generated in the electron gun and maintain its diameter in a region of the ion trap. No shielding is planned for the solenoid in order to enable use of its magnet field "tails" for the electron beam transmission in areas where use of other coils is difficult. The required magnetic field in the center of solenoid is determined by the combination of parameters (cathode emission current density, ion confinement time, tolerated level of impurities, ability of the electron collector to dissipate certain power). The solenoid is located on the EBIS platform and should require minimum maintenance for refilling of cryogens. (A portion of this WBS is funded by NASA)

1.1.1.2 Electron Gun

The EBIS electron gun generates the electron beam used for the ionization and confinement of ions in a trap. Since the electron beam propagates through the areas with very low potentials and with different magnetic fields the requirements on the laminarity of the electron beam are high. For this reason the magnetic field on the cathode is high enough to determine formation of the electron beam in a cathode-anode gap. The cathode material (IrCe) provides high emission current density with a lifetime of several thousand hours. The electron gun chamber is separated from the rest of the EBIS by two gate valves, which in a case of gun failure allows replacement of whole gun unit by a new one without venting the gun chamber and venting only small buffer volume between gate valves.

1.1.1.3 Drift Tube & Chamber Structures

Drift tubes are installed along the EBIS axis to control ion trap operation and propagation of the electron beam. Drift tubes are electrically isolated from the ground and connected to the external power supplies via electrical feedthroughs in a vacuum jacket. Vacuum chambers form a vacuum envelope around the EBIS with the pressure of residual gas in the range of 1×10^{-10} Torr. Three gate valves separate different parts of the EBIS for the purpose of maintaining high vacuum in parts that are not vented during modification or repair.

1.1.1.4 Stands, Platform Hardware

This includes the mechanical support structures for the EBIS, the electron gun, the LEBT line, and the external ion sources. It also include the 100 kV insulating platform for the EBIS source and its associated power supplies, as well as the electrical system required to put a ramp on the EBIS trap electrodes for fast ion extraction.

1.1.2 LEBT and External Ion Injection

The beamlines between the EBIS output and RFQ input.

1.1.2.1 LEBT

The LEBT is a transitional portion of the pre-injector and is used for:

- transmission and forming for the injection into RFQ of the ion beam extracted from the EBIS,
- transmission of the ion beam from the external ion injector into the EBIS,
- diagnostic measurements of the ion beams (total ion current measurements, ion beam content measurements),
- vacuum pumping of the electron collector.

The LEBT consists of two vacuum chambers separated by a gate valve; it contains optical electrostatic elements (deflectors, lenses), magnetic lenses for focusing the ion beam into the RFQ and diagnostic elements.

1.1.2.2 External Ion Injection

A set of two or more ion sources generating low charge state ions for injection into EBIS. This also includes ion optics, a switching station for electronically selecting the desired ion species for ion injection, ion current monitors, vacuum system and power supplies.

1.1.3 RF Structures

Resonant cavities used to accelerate or decelerate (for bunching) the ion beam. When radiofrequency power is fed into these resonant cavities, the appropriate electric fields for acceleration or deceleration are produced.

1.1.3.1 RFQ

The Radio Frequency Quadrupole (RFQ) is a resonant structure in which four long, continuous vanes or rods, machined with precise modulations and configured in a quadrupole geometry, provide bunching, focusing, and acceleration of the injected ion beam. This type of structure is able to provide efficient rf acceleration at the low energies ion beams have when initially extracted from an ion source. A 4-rod RFQ operating at 100.625 MHz is planned. (A portion of this WBS element is funded by NASA)

1.1.3.2 Linac

The Linac is a resonant structure, which generates time dependent axial electric fields to accelerate ions. When the rf field direction is reversed, the ion bunches are shielded from the decelerating fields by internal drift tubes. An “Interdigital-H” - type Linac operating at 100.625 MHz is planned. (A portion of this WBS element is funded by NASA)

1.1.3.3 Buncher Cavities

A resonant cavity in which the time dependent field in a gap is adjusted to decelerate the front of a beam bunch arriving at the gap, and accelerate the back of the bunch, so that all particles in the bunch arrive at a downstream point more closely spaced in time. By changing the phase of the cavity by 180 degrees relative to the bunch, it can be used to remove energy spread in the beam (“debuncher”) instead. (A portion of this WBS element is funded by NASA)

1.2 Controls

Networked, front-end interfaces will be connected via Ethernet to control console workstations and central C-AD servers. Full pulse-to-pulse modulation functionality will be provided. Custom application software will be provided as needed, but extensive re-use will be made of existing software designs with EBIS database additions.

1.2.1 Timing & Infrastructure

C-AD fiber optic infrastructure will be extended to the EBIS equipment area and a standard network switch and timing chassis will be provided. Workstations and monitor screens will be provided for console-level control access, along with supporting software and database configuration.

1.2.2 EBIS

Waveform generation and data acquisition for EBIS will be provided using the fiber-optically isolated PSI interface and VME function generator. The fiber link interface of these standard C-AD modules will be modified to operate at 50 to 100 kHz for this application. Additional fiber optic links will carry pulsed trigger signals to the high voltage platforms. Standard VME chassis will be provided. Minor modifications will be required to existing front-end software for the function generator. A custom console application program will be developed for power supply waveform control.

1.2.3 Accelerators & Beam Transport

Commercial and C-AD standard VME modules will be used to control magnet power supplies and beam-line instrumentation. Standard VME chassis assembly and timing modules will be provided for these systems and also for RF system interfaces. Front-end software effort will be mainly configuration and database setup. Existing console programs for beam line diagnostics will be modified to include the EBIS transport lines.

1.3 Diagnostics/Instrumentation

1.3.1 Faraday Cup

A fully destructive measurement is made when a detector head is plunged into the beam path to collect the entire ion beam. The captured charge is measured as a current in the processing electronics. Several types of detector heads can be employed depending on the characteristics of the desired measurement. Channeltrons or multichannel plates are used for fast high bandwidth response.

1.3.2 Current Transformers

A ferrite toroid wound with many turns of signal wire is positioned around a ceramic break in the beam transport, all enclosed in a protective shroud. This is used as a non-destructive technique to measure the ion beam current characteristics with respect to time. A separate set of wire turns on the toroid is used for injecting a calibration signal.

1.3.3 Profile Monitors

Transverse beam profiles are measured by plunging an array of thin wires into the beam path. Each of the wires collects the charge from the small portion of the ion beam it intercepts; this charge is detected as a current in the processing electronics.

1.4 Magnet Systems

1.4.1 EBIS Warm Solenoids

The EBIS warm solenoids consist of three solenoid magnets. The electron gun solenoid is designed with water-cooled hollow conductors, pancake-style coils and no iron return. The electron gun coil provides the necessary field for proper electron beam launching and transport. The electron collector solenoid is similar in design to the electron gun solenoid. The electron collector solenoid focuses the beam to allow for proper electron collector operation. The remaining magnet, the LEBT solenoid, is a pulsed solenoid located directly in front of the RFQ. The LEBT solenoid focuses the EBIS beam into the RFQ. The design of the LEBT solenoid uses pancake coils with a laminated iron return similar in design to the BNL Optically Pumped Polarized Ion Source (OPPIS) LEBT solenoid.

1.4.2 MEBT Quadrupoles

The EBIS MEBT quadrupole magnets are used to provide the necessary focusing for beam transport between the RFQ output and the Linac input.

1.4.3 HEBT Dipoles

The HEBT dipoles are two similar 73° bending dipoles. The basic design of the dipoles is a C style with the open end facing the outer curve to allow the chamber to have a port for the Tandem-to-Booster (TTB) line into the Booster. The magnets will be constructed of laminations of different sizes which when assembled will produce the required bend shape. The magnet coils will be made of water-cooled hollow copper conductor. (A portion of this WBS element is funded by NASA)

1.4.4 HEBT Quadrupole Magnets

The HEBT quadrupoles will be air-cooled Danfysik magnets. Originally used for other projects at BNL, these magnets are available for the EBIS beam line. These magnets will allow switching of values in ~ 1 second for running of different magnetic rigidity beams.

1.5 Power Supply Systems

1.5.1 EBIS

Power supplies to support EBIS itself:

- Solenoid, cathode, cathode heater, collector and grid supplies.
- Platform bias supplies and the transformers to isolate them.
- Drift tube supplies, Behlke switches, and transverse magnetic supplies.

(A portion of this WBS element is funded by NASA)

1.5.2 External Ion Injectors and LEBT

Power supplies to support two external ion sources, the transport from the ion sources to the LEBT, and the LEBT itself:

- Heater, arc pulser and extractor power grid supplies.
- Platform bias supplies and the transformers to isolate them.
- Supplies for electrostatic and electromagnetic steering elements and lenses.
- Mass analyzer and focusing solenoid power supplies.

1.5.3 MEBT, IH LINAC, and HEBT

Power supplies for the MEBT, IH LINAC, and HEBT:

- Pulsed quadrupole magnets and steering magnet power supplies.
- Linac drift tube quadrupole magnet power supplies.

- Pulsed bending magnet power supplies.
  (A portion of this WBS element is funded by NASA)

1.6 RF Systems

1.6.1 High Level RF

The final rf amplifier stages powering the RFQ, Linac, and three bunchers. This also includes the coaxial transmission line connecting the amplifier outputs to the rf cavities.

1.6.2 Low Level RF

The low power rf systems which provide the phase and amplitude controls for the high level rf systems, and frequency control for the resonant cavities.

1.7 Vacuum Systems
(A portion of this WBS is funded by NASA)

1.7.1 Beampipes/Chambers

Pipes or chambers that have vacuum pressure inside and provide a path for the ion to be transported, as well as provide a housing for special components inside the vacuum system.

1.7.2 Vacuum Instrumentation & Control

A PLC-based control system used to monitor and control the vacuum system and components such as gauges, pumps and valves.

1.7.3 Vacuum Pumps

Pumps used to evacuate or pump down a vacuum chamber from atmospheric pressure to the desired high vacuum or ultra-high vacuum range.

1.7.4 Vacuum Valves

Manual or pneumatically operated valves used to isolate vacuum pumps and/or a section of the beam line from another section or vacuum chamber.

1.8 Cooling Systems

The cooling system will use the excess capacity of the NSRL deionized water system to supply 325 gpm to the preinjector facility equipment. A high pressure flow loop will branch from this supply, consisting of a boost pump and heat exchanger, for two high pressure applications: the electron collector and the Linac quadrupoles. The present Linac chilled water system, which dissipates heat into the existing Linac cooling tower, will be extended for the air conditioning in the new building addition. Low flow chillers for tight temperature range control and special water conditioning will be used for the RF equipment, as necessary. The active on-line deionized water controls will maintain the required resistivity. The RF Linac chilled water loop will have a 4109 iron corrosion inhibitor control system.

1.9 Facility Modifications

1.9.1 Beam Access Port

A new access port for the EBIS beam line will be installed through the earth shielding from Linac to the Booster. (A portion of this WBS is funded by NASA)

1.9.2 Power modification

Provides for the relocation of existing power & tray in the Linac area where the EBIS beam line will be installed.

1.10 Installation

The major systems and components of the EBIS are installed at the facility site in building 930, including structural components, control systems, diagnostic and instrumentation systems, magnets, power supplies, RF systems, vacuum systems, and cooling systems. The installation effort also includes any minor additions or changes to the building and facility necessary to accommodate these systems and components.

1.10.1 Structural Components

The major structural components installed in the facility include the Electron Beam Ion Source (EBIS), RFQ, and Linac. Other components will include smaller devices located in the LEBT, MEBT, and HEBT beam transport regions, such as auxiliary ion sources (LEBT), bunchers, electrostatic beam transport devices, and beam monitoring devices.

1.10.2 Controls

Installation of controls for the entire project.

1.10.3 Diagnostics/Instrumentation

Installation and checkout of all diagnostics in the beamlines.

1.10.4 Magnet Systems

The magnet systems installed in the beam transport line include dipole, quadrupole, and solenoidal magnets, and steerers. Also includes survey of elements.

1.10.5 Power supply Systems

Installation of all power supplies in their final locations, the connection of power from breaker boxes to the supplies, and the connections from the power supplies to the elements.

1.10.6 RF Systems

Installation of the rf power supplies, as well as the connection of the coaxial transmission line between the rf amplifiers and the rf cavities.

1.10.7 Vacuum Systems

Installation of beampipes, chambers, pumps, and valves. Also includes the leak checking and bakeout of systems.

1.10.8 Cooling Systems

Installation of all cooling systems.

1.11 Project Services

Level of effort tasks associated with the daily management, oversight, and assessment of the project.

1.11.1 Project Management & Support

This WBS contains the effort associated with the Project Office at BNL for the EBIS. The effort includes: the CPM, Project Controls, ESH&Q, installation and conventional facilities coordination, financial oversight, documentation and reporting, and the Project Office secretary.

1.12 Commissioning

System integration with beam. This includes beam tuning and characterization from the EBIS, through the LEBT, RFQ, MEBT, Linac, and HEBT. Activities will include the measurements of beam currents, profiles, emittances, verification of beam energy and energy spread, and measurement of charge state distributions for several ion species. Commissioning ends when the performance required for CD4 has been demonstrated.

1.13 R&D

A development program which uses the existing Test EBIS to verify the validity of several key design choices related to the extraction, acceleration, and initial transport of the ion beam from the EBIS. The R&D also includes testing the EBIS electron collector design for thermal load handling. These developments will serve to reduce technical and schedule risks on the project. The R&D includes the procurement of the full power electron collector, which will later be used on the RHIC EBIS. Procurement of a 100 kV isolation transformer, high voltage isolation, and some EBIS power supply modifications will allow the EBIS to be operated from a high voltage platform, producing beams at the final energy required for injection into the RFQ. Finally, a prototype of the final LEBT design will be built and tested. (A portion of this WBS element is funded by NASA)